SW06 Shallow Water Acoustics Experiment Data Analysis

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LONG TERM GOALS

The long term goal of our shallow water acoustics work is to understand the nature of low frequency (10-1500 Hz) acoustic propagation and scattering in shallow water when strong oceanic variability in the form of fronts, eddies, boundary layers, and internal waves is present.

OBJECTIVES

Our primary objective this year was to continue the analysis of the data set collected by the SW06 experiment, with emphasis on internal wave effects, and model it with theory and numerical models. 3-D acoustics and oceanographic effects are of particular interest.

APPROACH

In performing the data analyses, we concentrated on the effects of realistic coastal nonlinear internal waves on acoustic propagation. That is, we have included the effects of truncated internal waves, curved internal waves, internal wave directional spectra, and crossing internal wave trains. We have papers both in press and submitted on the first two topics, and have made substantial progress on the other topics. We are also continuing to look at the azimuthal variability of transmission loss and noise due to coastal oceanographic effects, a closely related topic.

WORK COMPLETED/ACCOMPLISHMENTS

In the previous year, we produced the initial papers on the data analyses for a JASA-EL Special Issue, which appeared in 2008. This year, we aimed at producing more in-depth analyses for a Special Issue of IEEE JOE, as well as for JASA. Our two main results were a paper on the effects of truncated internal wave ducts (JASA, in press) and a paper for the IEEE JOE Special Issue (submitted), the latter of which we will discuss here.

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14. ABSTRACT
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15. SUBJECT TERMS

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RESULTS

It is apparent from the SAR image in Figure 1 that truncated internal waves, curved internal waves, internal wave directional spectra, and crossing internal wave trains all exist in the coastal and are first order features of the nonlinear internal wave field. In analyzing these waves, we used a combination of theory, data analysis, and numerical modeling to understand the wave effects upon the acoustic field. We will just show the numerical model results here, due to space limitations. In Figures 2, 3 and 4, we show the effects of putting the source inside an internal wave train, exterior to a wave train, and interior to a wave train respectively. Strong caustics and shadow zones are seen, as well as ducting, horizontal Lloyd's mirror effects, and classical whispering gallery effects.

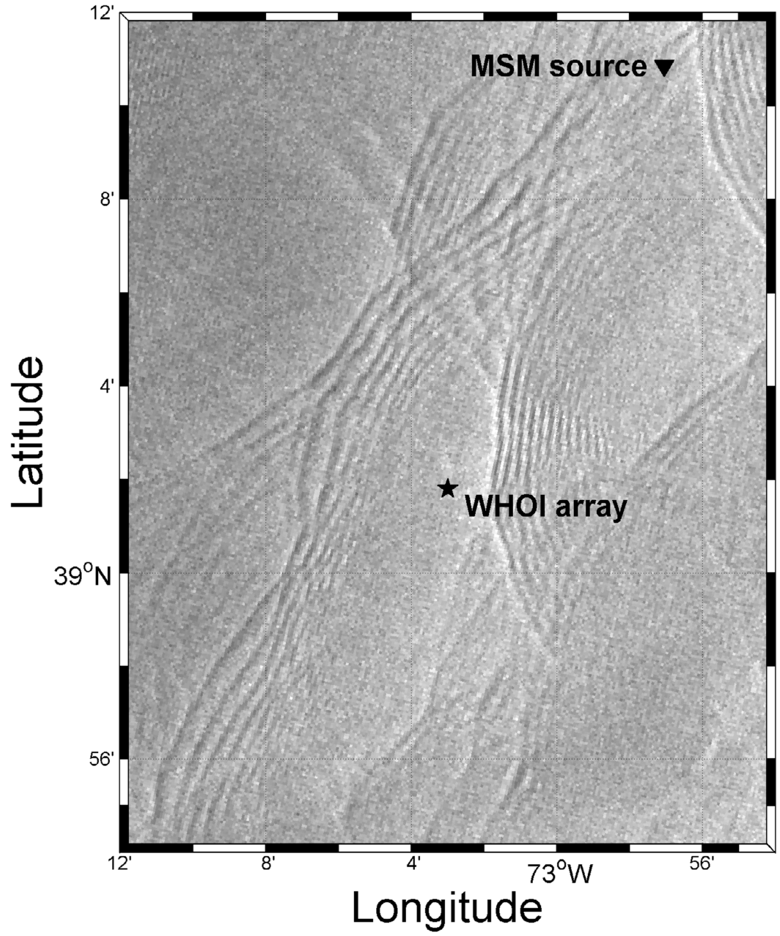

Figure 1. SAR image of curved nonlinear internal waves in the SW06 experimental area. Range from U. Miami acoustic source (MSM) to WHOI array is 19.7 km, and orientation is along-shelf.

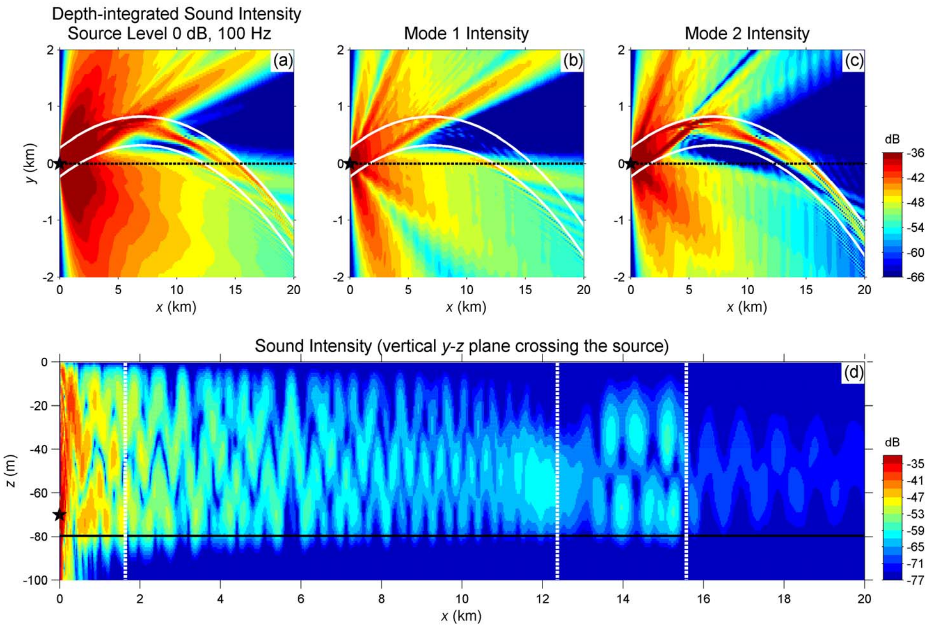

Figure 2. (a) Depth integrated (averaged) energy at 100 Hz, (b) depth integrated mode one intensity, and (c) depth integrated mode two intensity. Panel (d) shows a vertical slice of sound intensity at y = 0. Note clear appearance of mode 1 and 2 between ranges 12 and 15 km (in the internal wave duct). Radius of curvature is 45 km here.

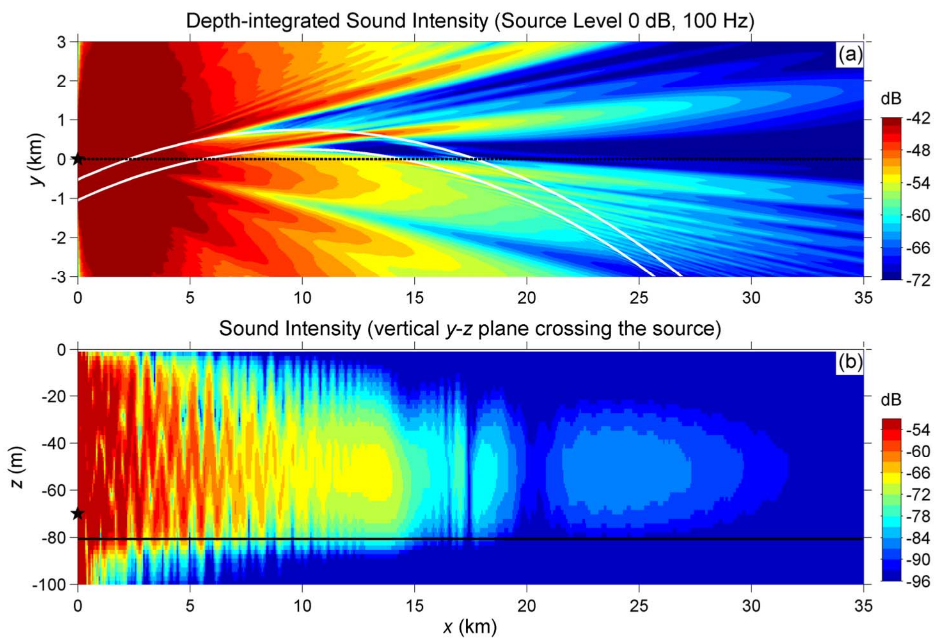

Figure 3. Shadowing and horizontal Lloyd's mirror effects seen due to a curved nonlinear internal wave of 40 km radius. (a) Depth integrated (averaged) energy at 100 Hz, and Panel (b) shows a vertical slice of sound intensity at y = 0.

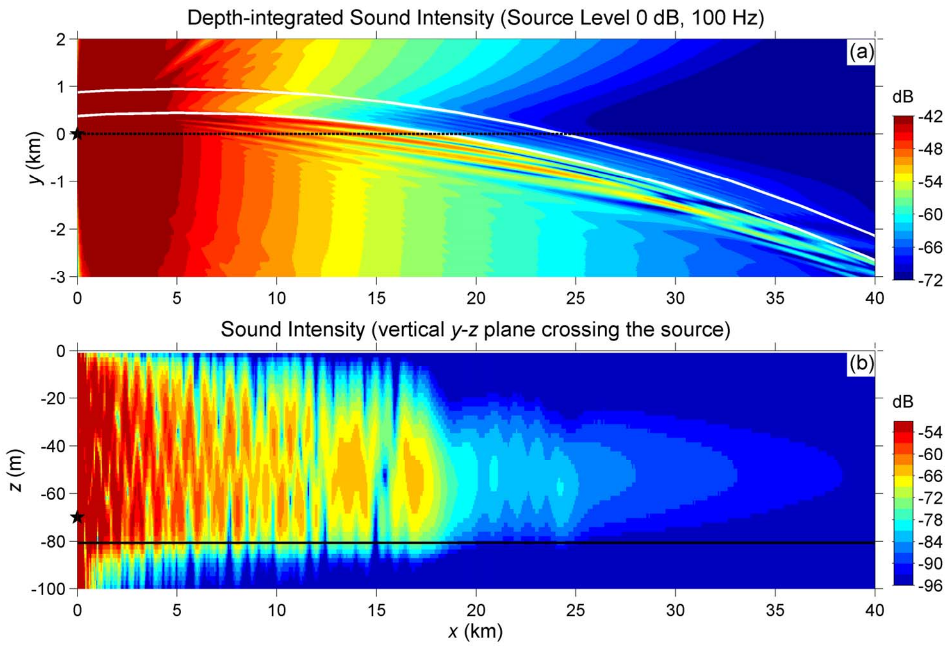

Figure 4. Whispering gallery, duct penetration, and shadowing effects seen due to a curved nonlinear internal wave of 200 km radius. (a) Depth integrated (averaged) energy at 100 Hz, and Panel (b) shows a vertical slice of sound intensity at y = 0.

IMPACT/APPLICATIONS

The impact of our experiment should be: 1) an increased understanding of the propagation of sound through the complicated coastal oceanography of the nonlinear internal wave field and 2) an eventual capability to model these effects for use in sonar performance prediction applications.

TRANSITIONS

One eventual transition of our analyses will be to ONR's Uncertainty DRI program, where the interest is in "the error bars" in ocean acoustic field and system performance prediction.

RELATED PROJECTS

The SWARM acoustics/internal wave study, the PRIMER acoustics/shelfbreak front study, and ASIAEX were direct predecessors of SW06, and examined some of the same acoustic scientific issues, only with far fewer measurement resources. The "Non-linear internal waves initiative" (NLIWI) is strongly related to our SW06 effort via the environmental support that the oceanographic moorings (and other PO measurements) provided. The just-completed QPE experiment, stressing acoustic and environmental uncertainty in a coastal environment, is also related.

PUBLICATIONS

[1] Y.T.Lin, T.F. Duda, and J.F. Lynch, "Acoustic mode radiation from the termination of a truncated nonlinear internal gravity wave duct in a shallow ocean area", *J. Acoust. Soc. Am.* (2009) (published, refereed).

[2] J. Lynch, Y.T Lin, T.F. Duda, and A.E. Newhall, "Acoustic ducting, shadowing, refraction, and dispersion by curved nonlinear internal waves in shallow water", *IEEE J. Oceanic Eng'g.* (2009) (submitted, refereed).